EIC Gas Tracking R&D Overview

Matthew Posik
Temple University
EIC User Group Meeting
UC Berkeley
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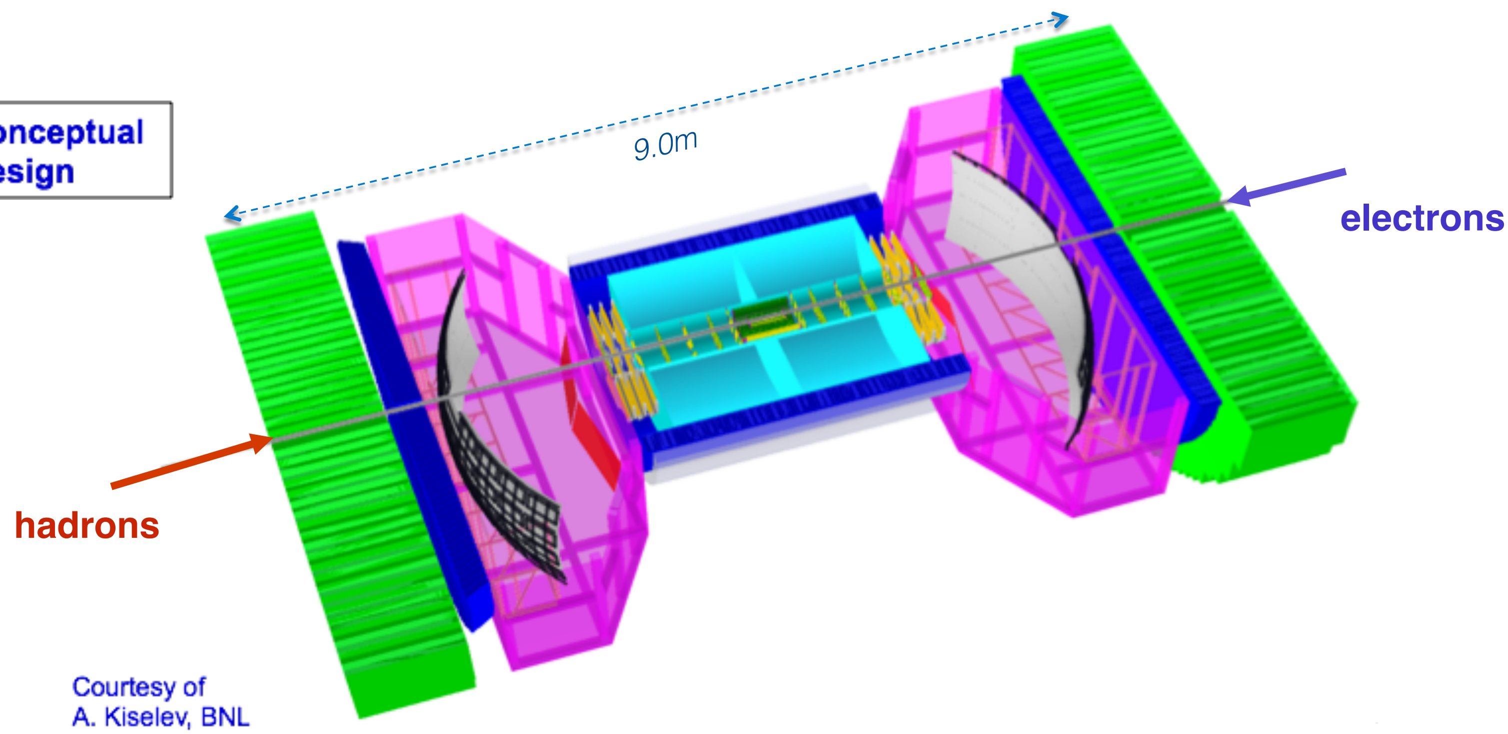
Outline

- Brief EIC Overview
- Micropattern Basics
- Some Recent R&D Publications
- Forward/Rear Trackers
  - Common GEM Design
  - Unique Assembly/Readout Designs
- Barrel Region
  - Fast Compact TPCs
  - Hybrid TPC Readout
  - Barrel Micromegas Detector

EIC Overview

- The EIC looks to answer questions essential for our understanding of visible matter and to further investigate and test the theory of QCD
- EIC requires **fast**, **low mass**, **high resolution, high efficiency, cost efficent** tracking
- Tracking sectors can be split into two regions

EIC Conceptual design



Courtesy of
A. Kiselev, BNL

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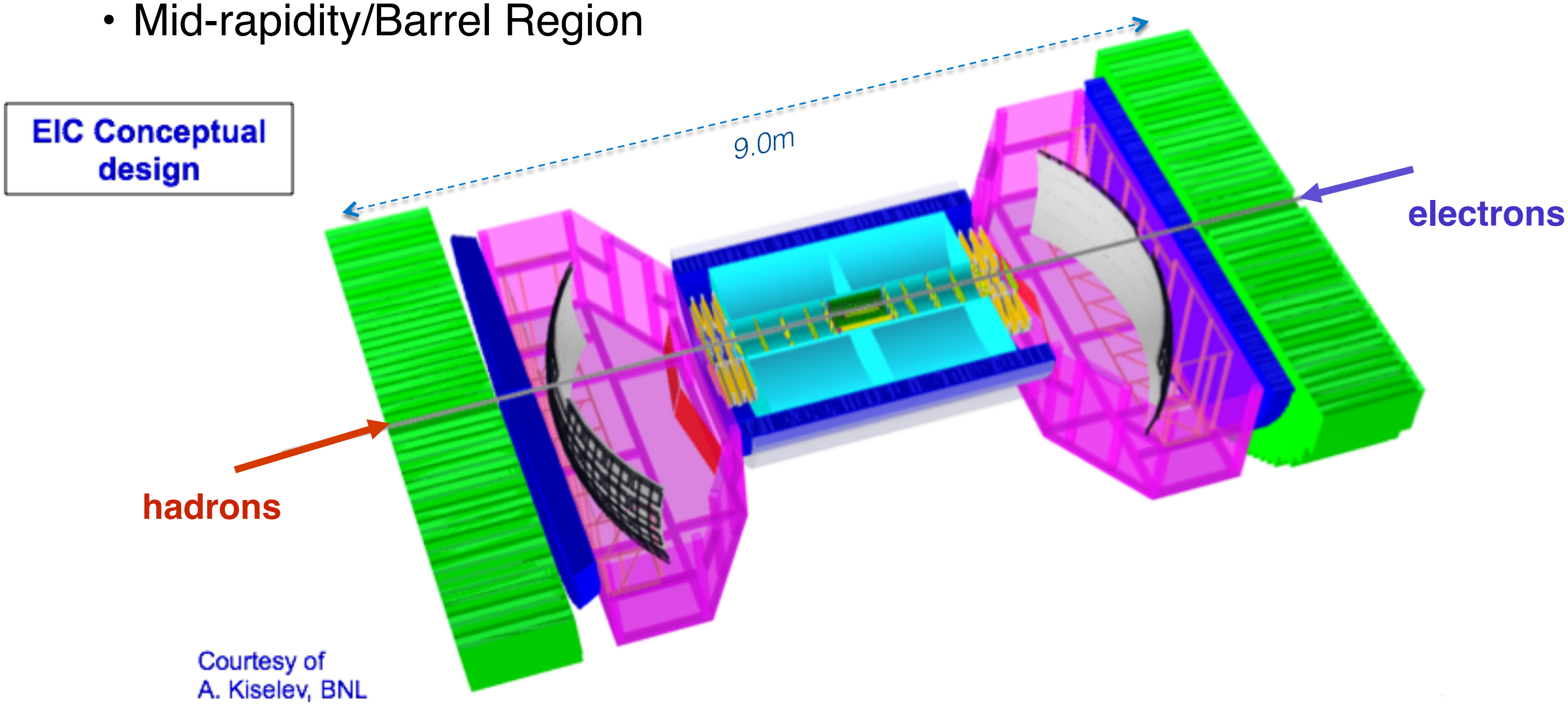
  - Forward/Rear Region
  - Mid-rapidity/Barrel Region



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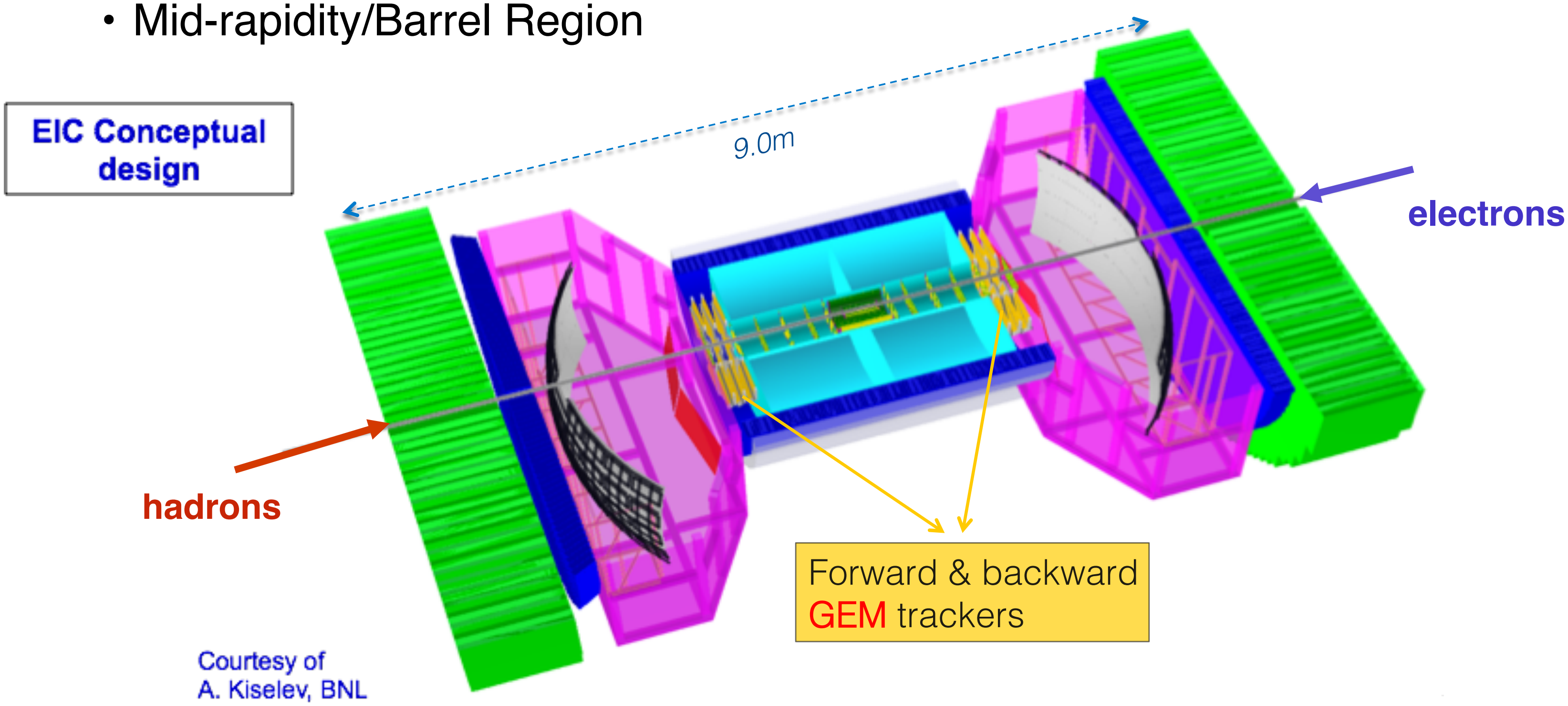
  - Forward/Rear Region ⇨ **GEM Trackers**
  - Mid-rapidity/Barrel Region



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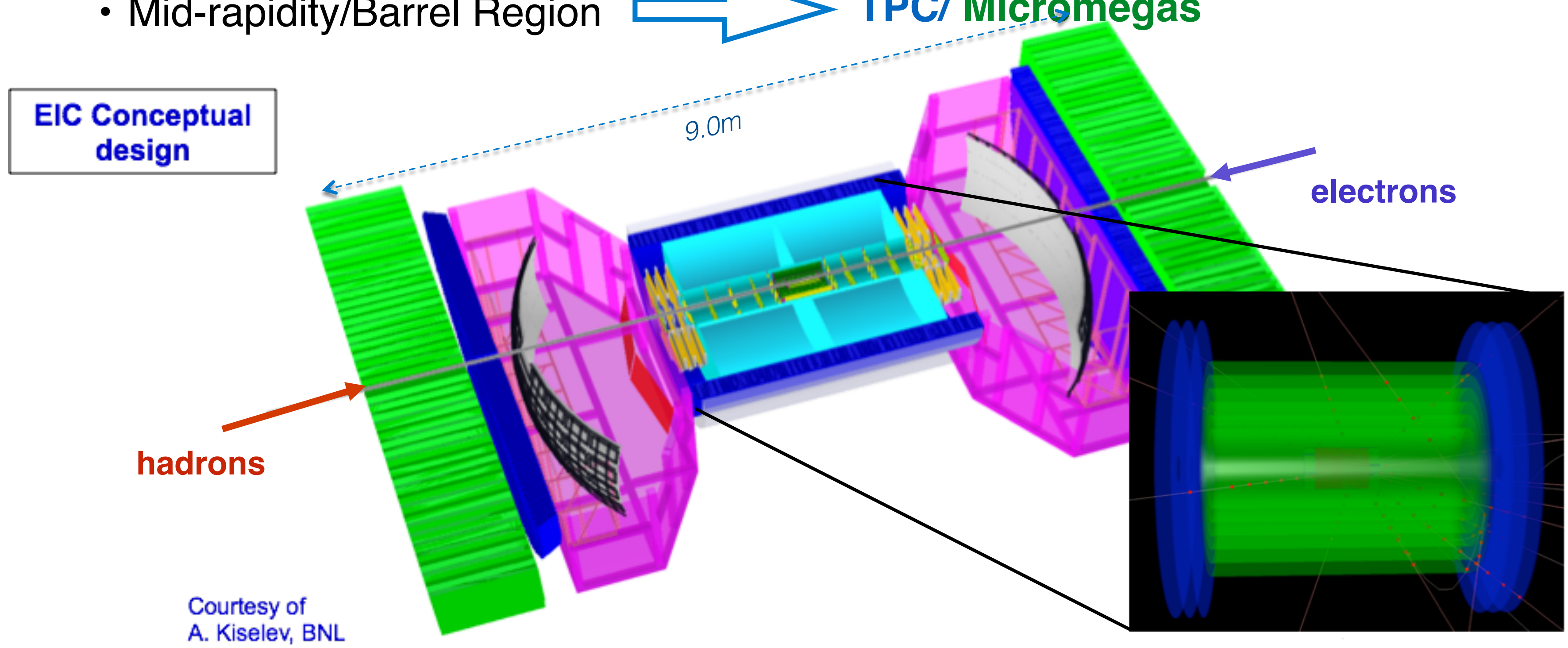
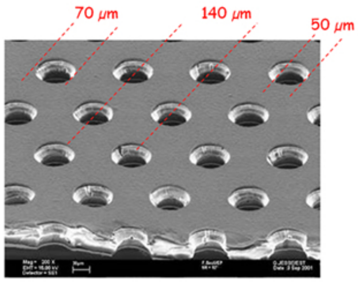
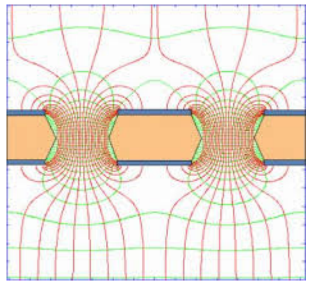
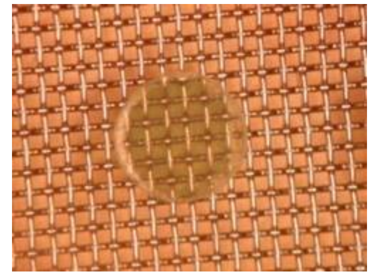
- EIC requires **fast**, **low mass**, **high resolution, high efficiency, cost efficent** tracking
- Tracking sectors can be split into two regions
  - Forward/Rear Region → GEM Trackers
  - Mid-rapidity/Barrel Region → TPC/ Micromegas

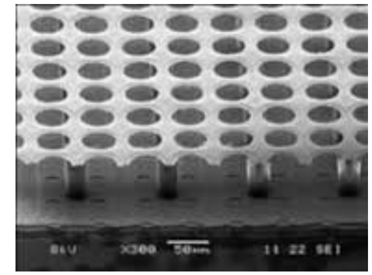


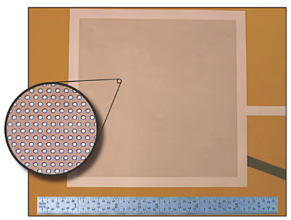
Gas Electron Multipliers (GEMs) and Micromegas (MMGs)



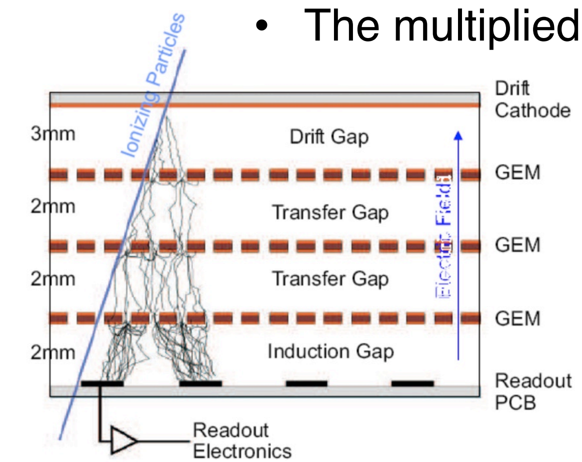


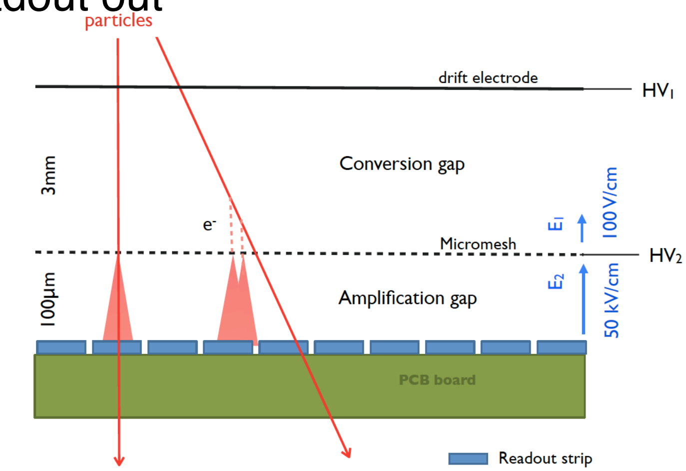




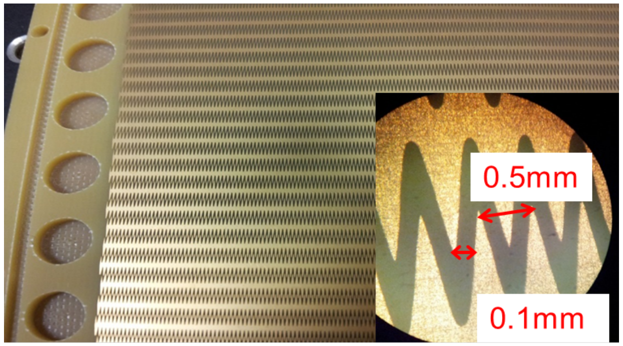


- Two common micropattern detectors are GEMs and MMGs
- GEMs and MMGs are based on electron multiplication via ionization
- In coming particle ionizes the gas
- The increase in the electric field in GEM holes and MMGs mesh leads to avalanching effects
- The multiplied signal can then be readout out





Recent R&D Publications



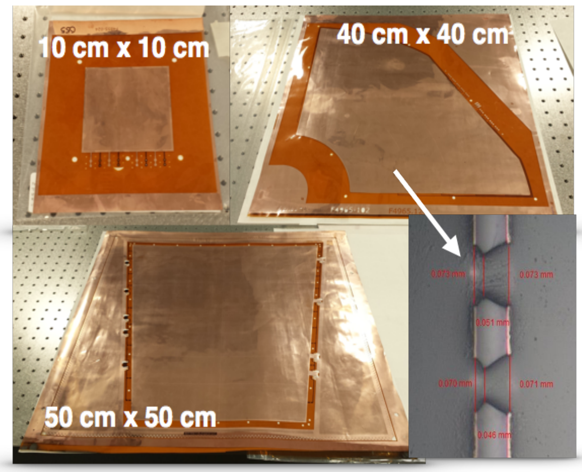
NIM A 811 (2016) 30-41

Florida Institute of Technology (FIT)

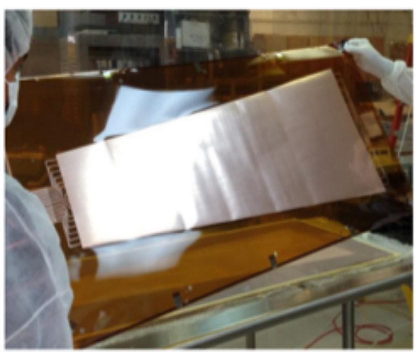
- Recently submitted a results of their large area (~1 m) triple-GEM detector to NIM A for publication.
- Successfully used zig-zag readout as a means to maintain good sp atial resolution while reducing number of readout channels needed
- σ_{ϕ} = 193 μrad

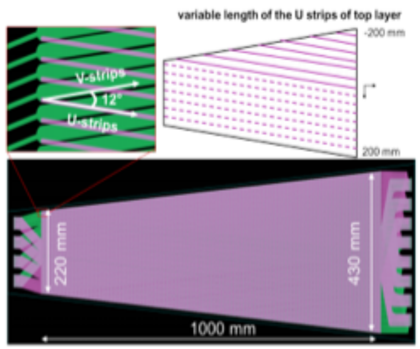
Temple University (TU)

- Have been working with US company Tech-Etch towards commercializing la rge-area GEM foils.
- Recently published results of electrical and geometrical foil quality



NIM A 802 (2015) 10-15



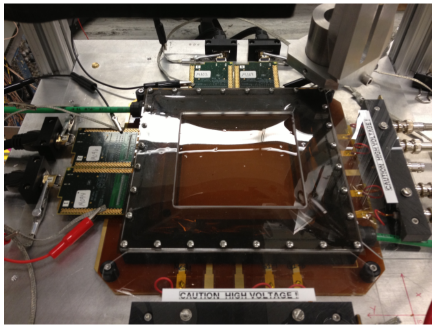


NIM A 808 (2016) 83-92

University of Virgina (UVa)

- Recently published results on their large-area (~1 - m)/ light weight triple GEM detector
- The detector successfully implemented 2D stereo -angle (U-V strips) readout
- σ_r = 550 μm, σ_{ϕ} = 60 μrad

Recent R&D Publications



IEEE Trans. Nucl. Sci. (submitted)

Brookhaven National Lab (BNL)

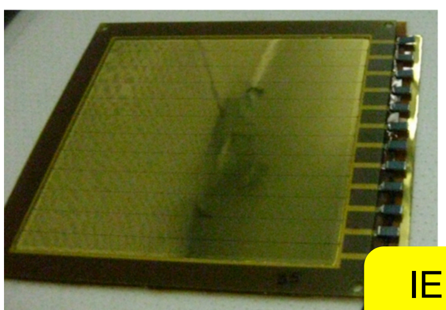
- Study position and angular resolution using a GEM detector
- Measure 2D charge location
- Use TPC configuration to measure the 3rd coordinate via the charge clus ter drift time
- Investigated different readout structures

Yale University

- Investigate ways to improve the tracking and energy resolution of a TPC
- More information in a few slides!

Publication In preparation

Stony Brook University



IEEE Trans. Nucl. Sci. Vol. **62**, No. 6 (2015)

- Testing a RICH detector for particle ID
- Uses 5 GEM foils as amplification device with hig h efficiency for single photo-electons
- Photosensitive GEM coated with CsI
- Developing large mirror with good reflectivity in V UV (λ = 100-200 nm)

Assembly and Readout Methods

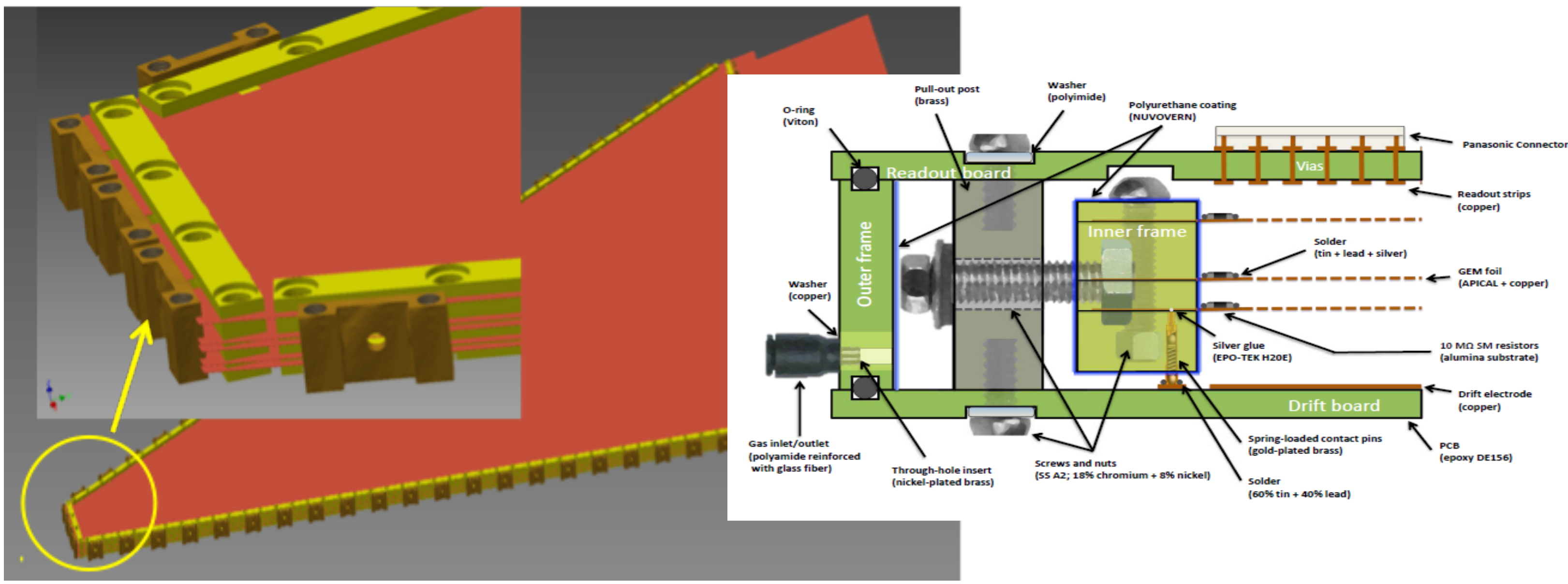
- Three institutions: FIT, TU and UVa will each use different detector assembly techniques to build large area triple-GEM detector prototypes.

FIT

- Mechanical stretching, no spacers in active area and allow foils to be changed
- Will use zig-zag strips for readout structure

Assembly Method: FIT

- Will use a **modified** CMS mechanical stretching technique
- The CMS GEM collaboration currently uses solid PCB boards for the drift and readout boards
- The **modified version** will use a stack of 5 foils: 3 GEMs + 1 drift foil + 1 readout foil. Supporting structures are frames with windows (e.g. Mylar foil)



Courtesy of A. Zhang

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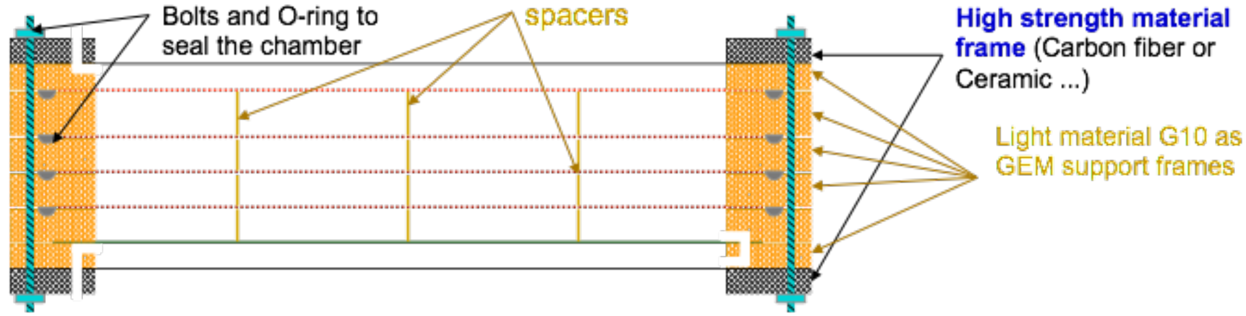
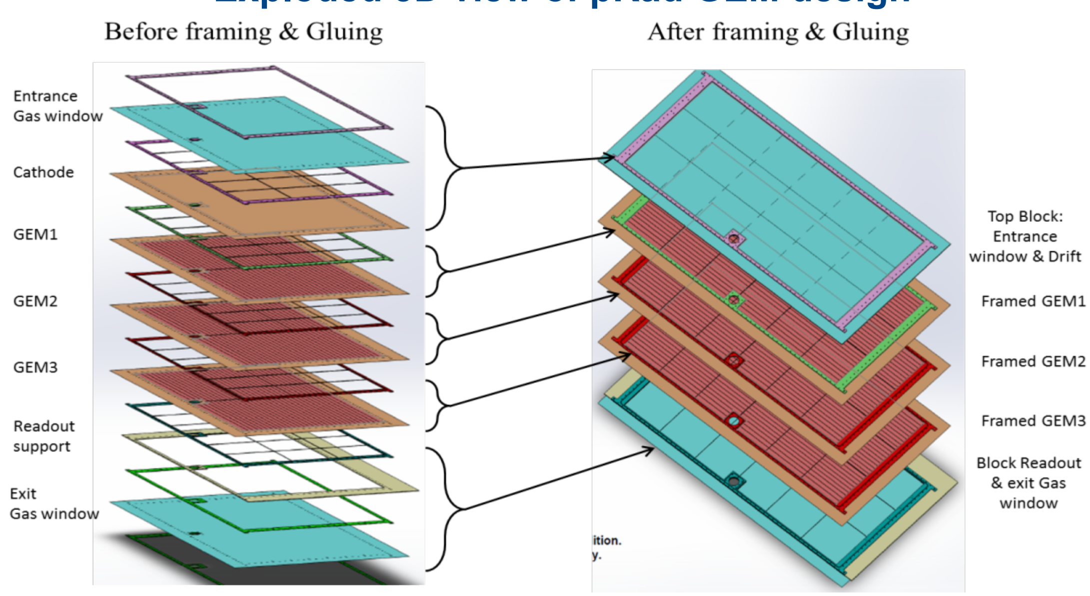
UVa

- Glue foils to frames that are held together by screws. Allows the foils to be changed
- Will use U-V strips for readout structure

Assembly Method: UVa



Exploded 3D view of pRad GEM design



- Low material in active area
- use spacers between the foils
- Light material for GEM frames
- High strength material for external support frames
- Bolts and o-rings to seal the chambers

Courtesy of K. Gnanvo

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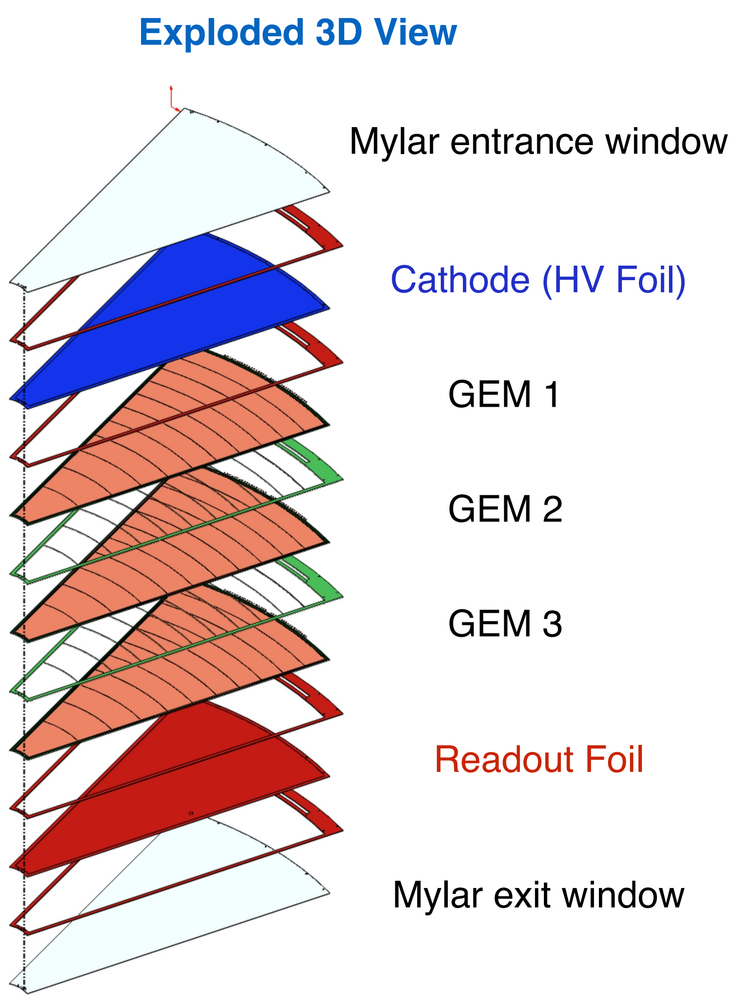
TU

- Glue foils to frames that are glued together. Foils can not be removed, but this method presents the lowest material budget.
- Will use r-phi readout structure

Assembly Method: TU



- Low material in active area
- use spacers between the foils
- Light material for GEM frames
- Material budget is further minimized by gluing the frames together (no need for bolts or screws)

Assembly and Readout Methods

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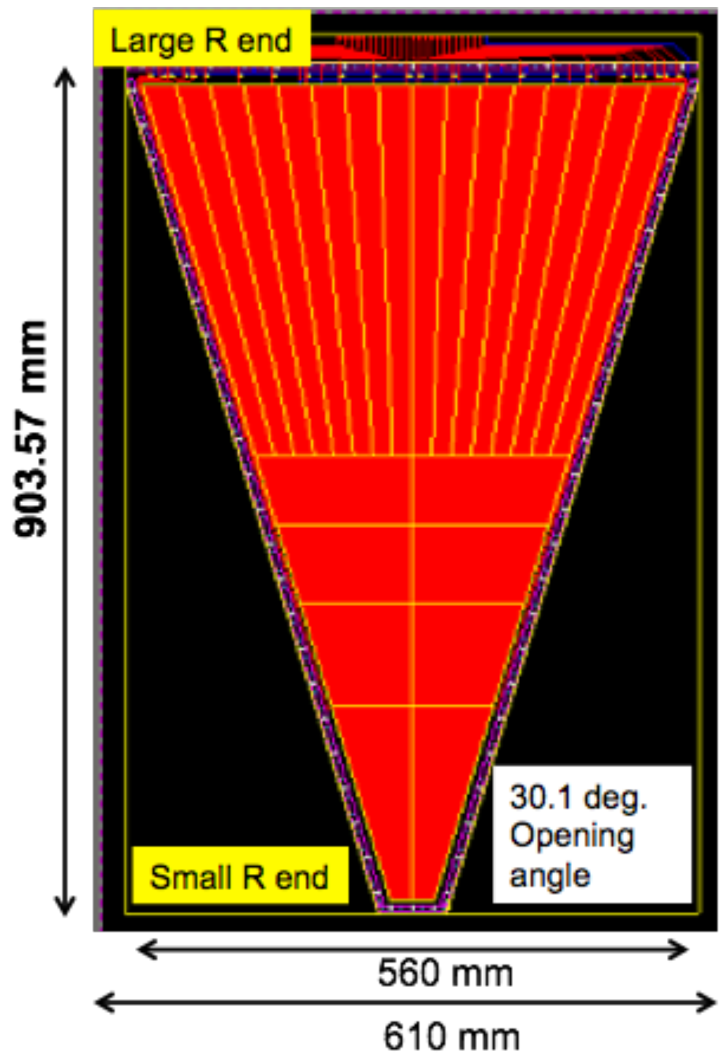
- The three groups have designed a common 1-m scale GEM foil which satisfies the different groups assembly requirements.

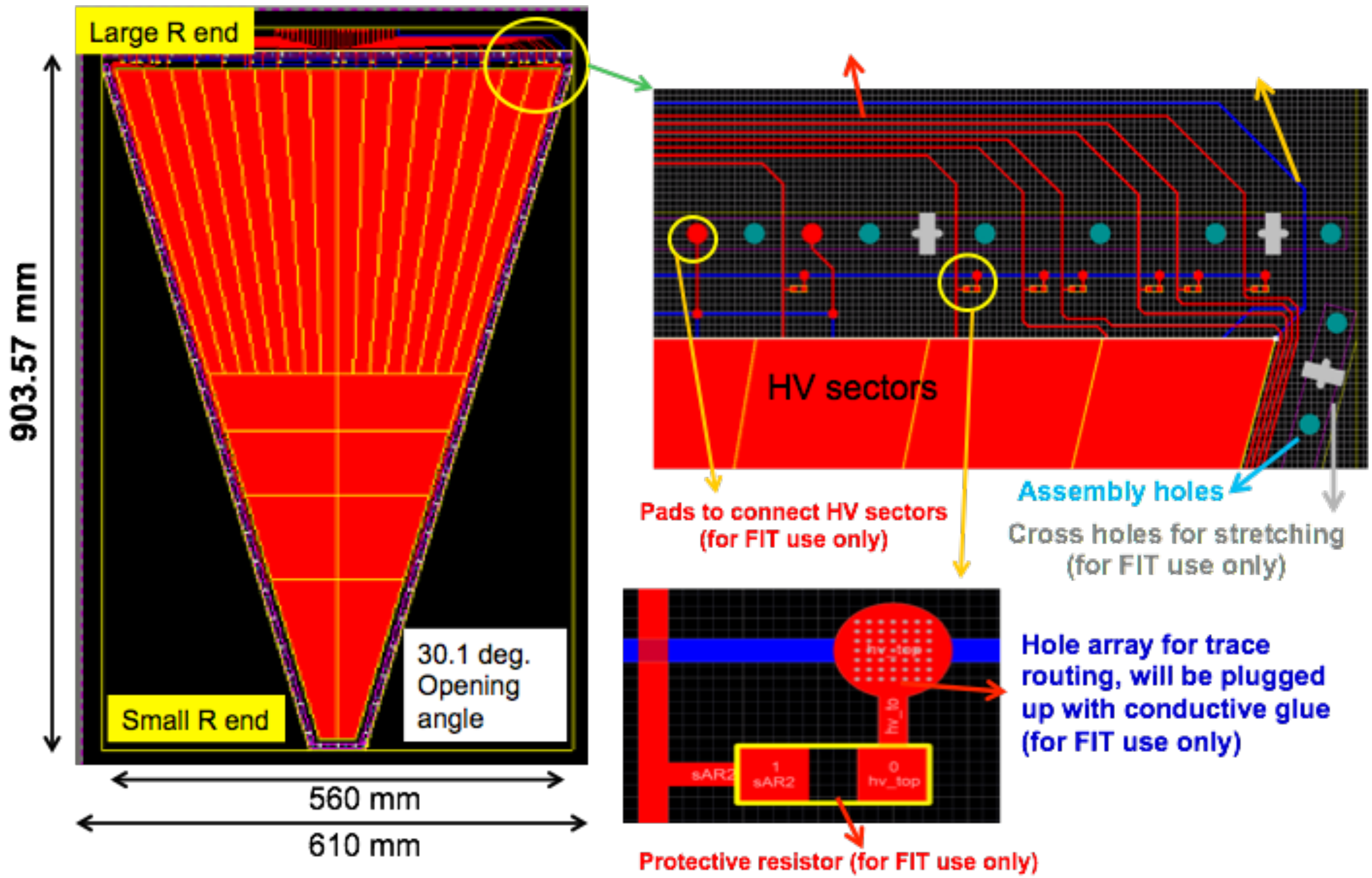
Common GEM Foil Design



Courtesy of A. Zhang

- Foil width (at large R end) is **limited** to **560 mm**, due to material width (610 mm) and space needed for foil production (25 mm margin)
- Active area is trapezoidal, and has a length of 903.57 mm and widths of 43 mm and 529 mm.
- Opening angle of the trapezoid is 30.1^{o}. which will allow for some overlap when using 12 triple-GEM detectors to form a disk.
- Active area is divided 26 sectors of ~100 cm^2 per sector, with 0.1mm gaps between each of the sectors
  - 8 HV sectors in the R direction (inner R)
  - 18 HV sectors in the azimuthal direction (outer R)
- HV connections are made from the top of the foil (large R end)

Common GEM Foil Design



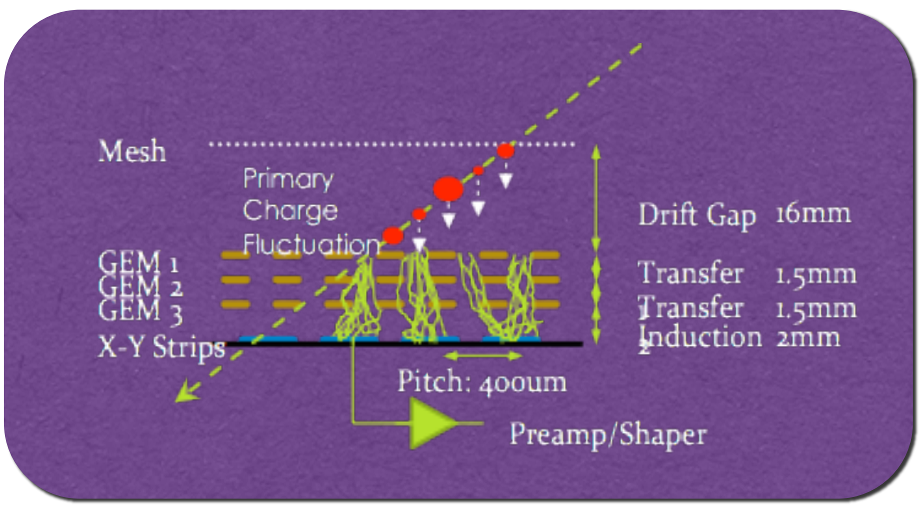
Courtesy of A. Zhang

Traits of Planar Tracking Detectors

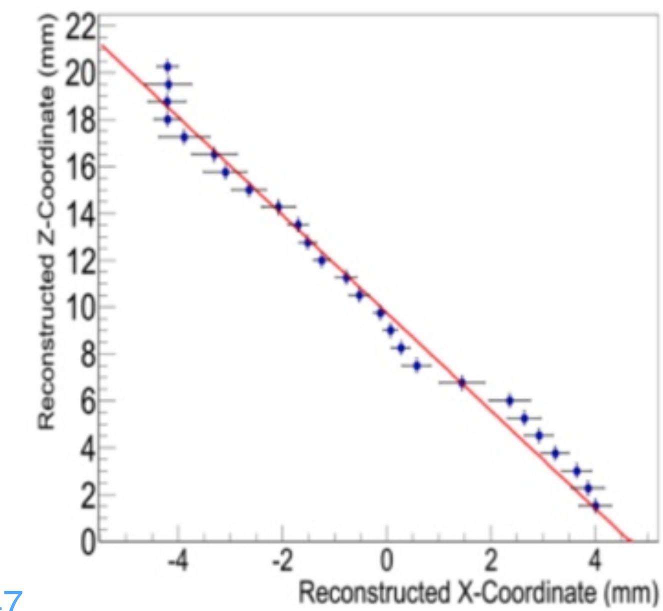
- Tracking detectors need to measure a range of angles
- Multiple detectors need to be separated by some distance in order to measure the angle ⇨ **More material**
- Position resolution typically deteriorates with increasing angle

Mini-Drift GEM Tracker (BNL)

- GEM detectors provide 2D coordinate information using segmented strip or pad readouts
- They can also be used in a TPC like configuration where the drift time of the collected charge can be used to reconstruct the 3rd coordinate
- The Mini-Drift GEM detector was a hybrid of these two configurations
- Investigate the angular and position resolution of a reconstructed track vector using two different readout setups



arXiv:1510.01747



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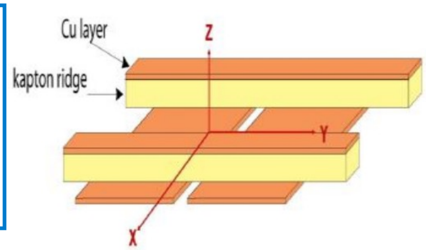
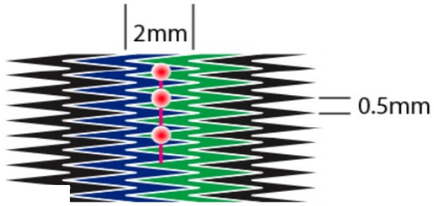
Mini-Drift GEM Tracker (BNL)

Two readouts were tested

arXiv:1510.01747

Compass style XY strips with 80 um wide top strips and 350 um wide bottom strips separated by a 50 um Kapton layer , each with a pitch of 400 um.



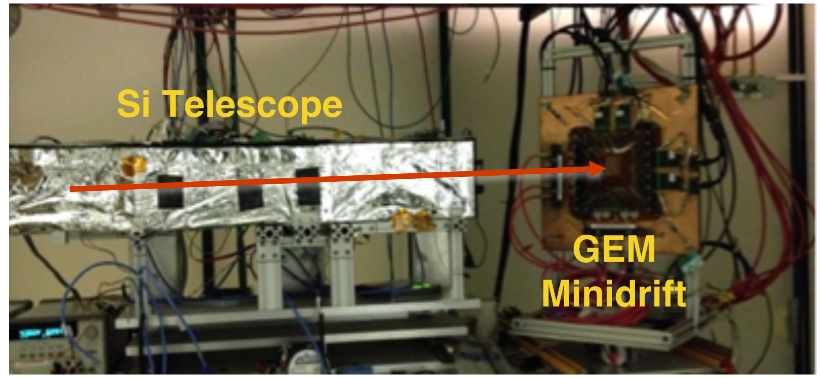


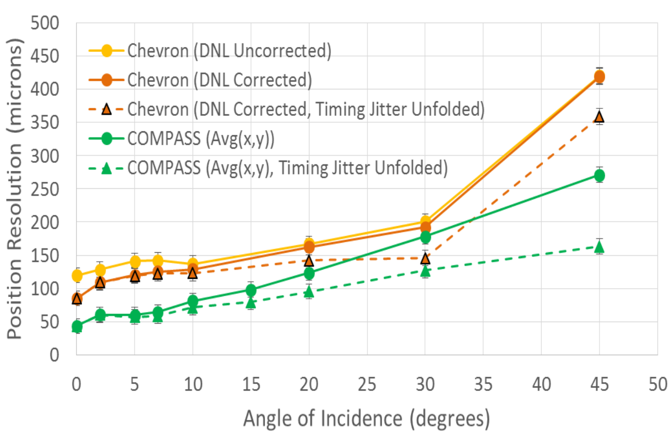
Chevron readout structure with interleaving zigzag electrodes with a pitch of 0.5 mm and 2 mm spacing

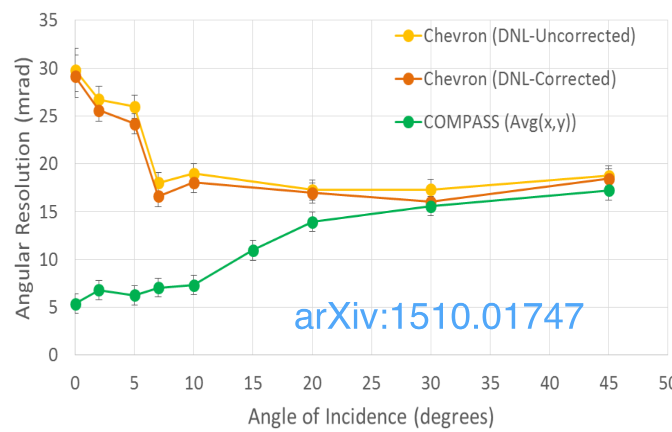
- Typically 2D readouts are used, but require **many small pads** to get good spatial resolution.
- Cheveron readouts can be used with a large pad size to obtain a resolution that is much smaller than the pad size by exploiting the charge sharing between interspersed electrodes

Mini-Drift GEM Tracker (BNL)

- Si telescope detector used to find track info:
  Position Resolution ~ 17µm
  Angular Resolution ~ 10 µrad
- Compass strips show good position resolution
- ~50 µm (at 0°) to ~160 µm (at 45°) and
  angular resolution ~5 mrad (0°) to ~18 mrad (45°)
- Cheveron pads give position resolutions < 150 µm at angles < 30° with much coarser segmentation
- Cheveron angular resolution worse than the Compass strips at small angles, but become comparable at larger angles



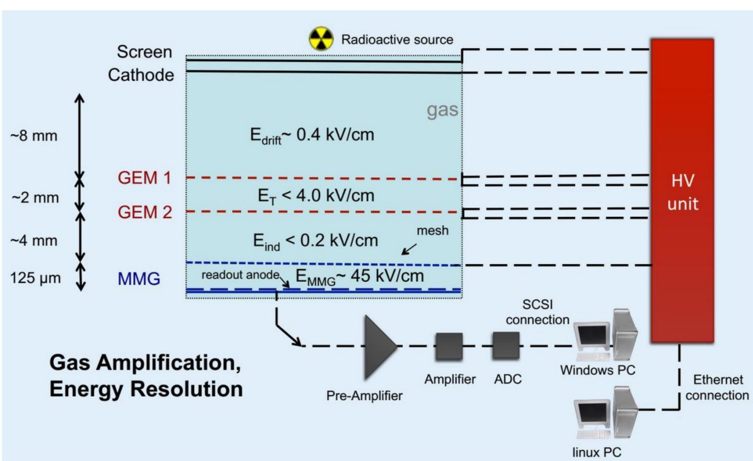




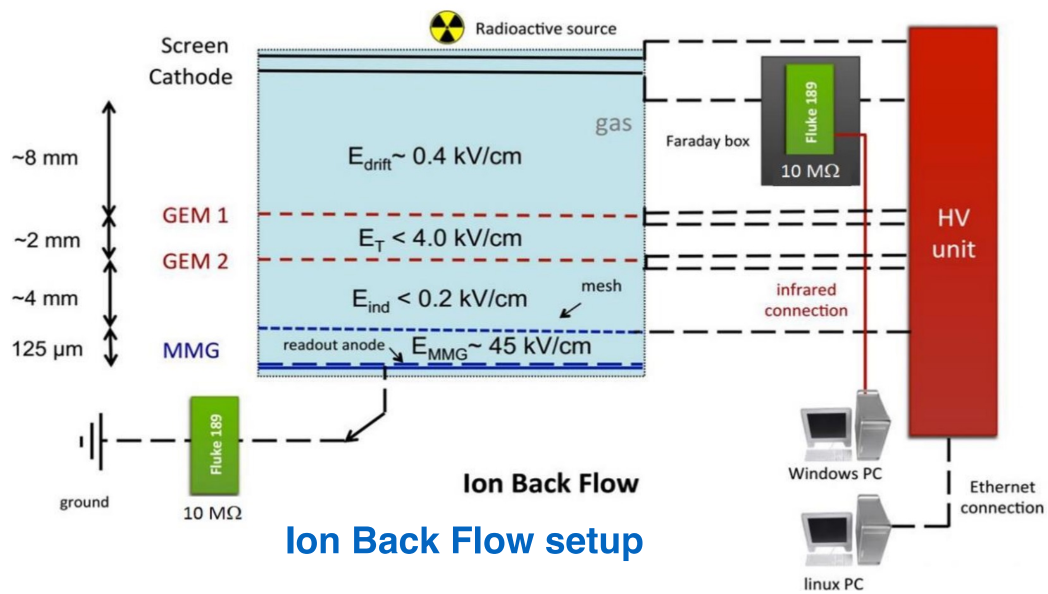
Hybrid TPC Readout (Yale University)

- Two key gain parameters for a TPC are **energy resolution** and **ion back flow** (IBF)- ions that flow back through the drift volume.
- With the ion's **drift velocity** being so **low** (compared to electrons), they can build up in the TPC drift volume and **distort** the drift field.
- The hybrid TPC readout uses **2-GEMS + MMG** to try and minimize the IBF in a TPC while keeping good energy resolution.

eRD6 Progress Report July 2015



Energy resolution setup

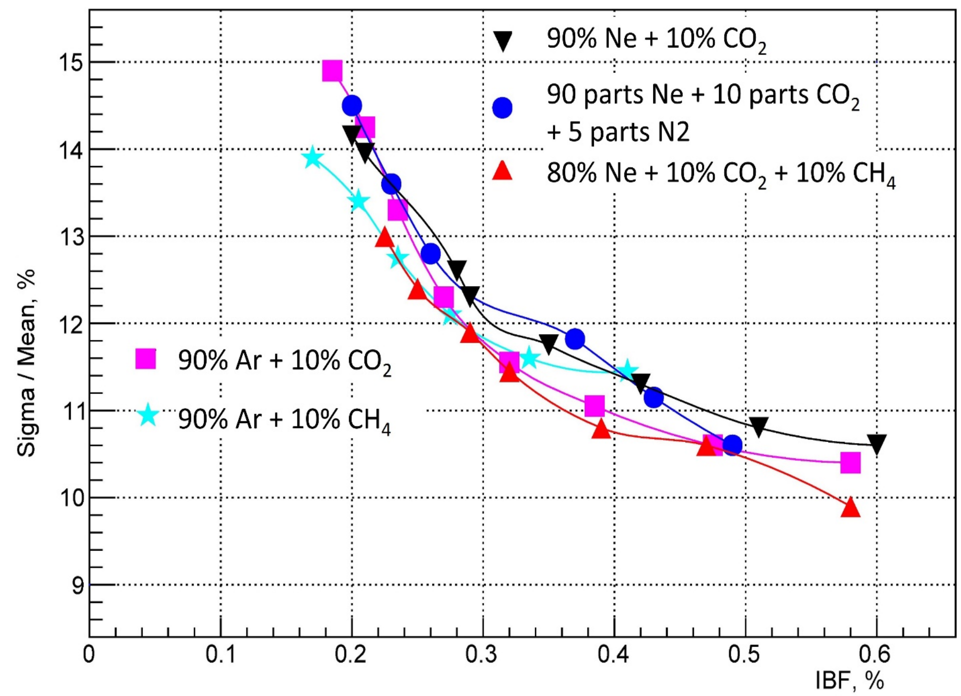


Ion Back Flow setup

Hybrid TPC Readout: 2-GEM + MMG (Yale University)

- Energy resolution for 55Fe x-ray vs. IBF for various gases
- Each curve represents a gas mixture
- Points along a particular curve are for different MMG voltages, where the GEM voltages were varied to keep the overall gain at ~2000
- Results show it is possible to obtain **IBF** flow **below 0.5%** while maintaining a good **energy resolution** (**better than 14%**)

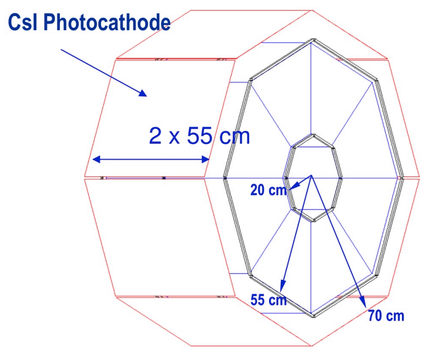
Ion Back Flow Results

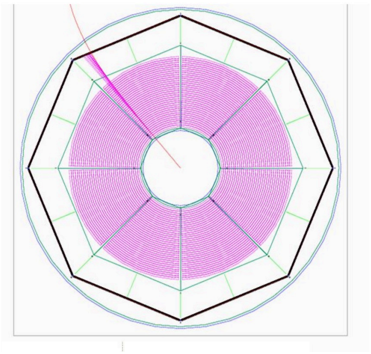


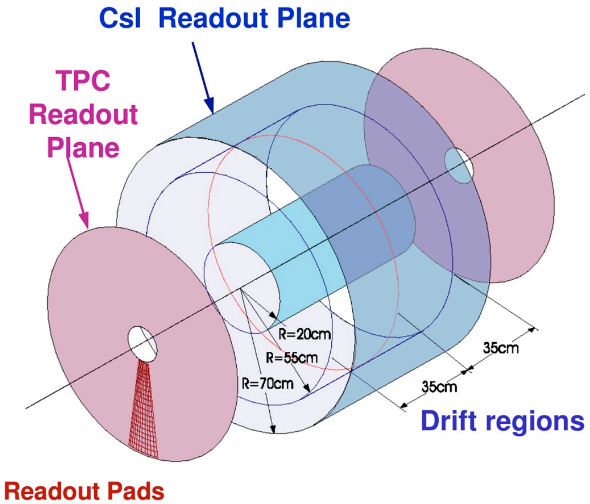
eRD6 Progress Report July 2015

TPC-Cherenkov Detector

- Develop a compact fast TPC using GEM readout detectors, that works with Cherenkov gases.
- Low mass tracking, multiple space point measurements, particle ID via dE/dx, and detection of Cherenkov light
- CsI GEM detector would allow for electron ID/ hadron rejection.
- Concept previously designed for sPHENIX





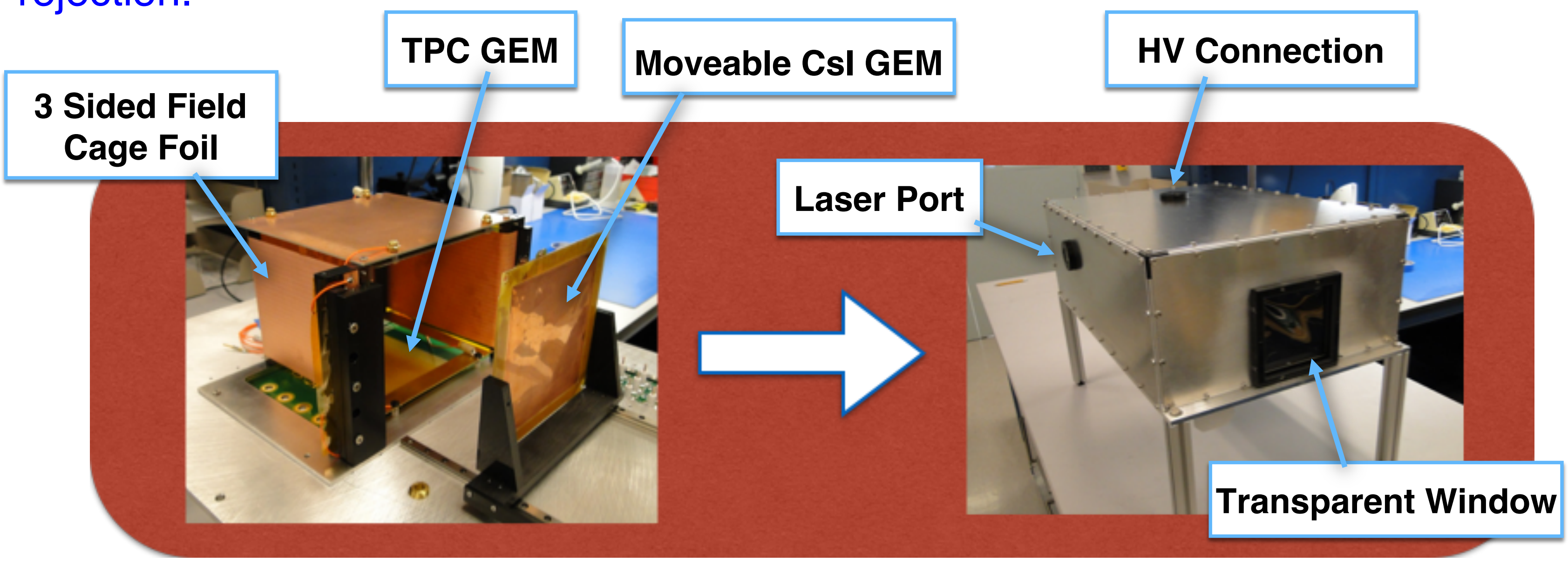


C. Woody EIC Tracking R&D Workshop, Temple University, 5/19/15

TPC Cherenkov Detector (BNL/SBU)

TPC-Cherenkov Detector

- Develop a compact fast TPC using GEM readout detectors, that works with Cherenkov gases.
- Low mass tracking, multiple space point measurements, particle ID via dE/dx, and detection of Cherenkov light
- CsI GEM detector would be essentially hadron blind, allowing for electron ID/ hadron rejection.



TPC Cherenkov Detector (BNL/SBU)

- Electric field distortions due to photosensitive GEM and wire plane of the field cage typically **below 1%** with Cherenkov mesh 15 mm from wire plane

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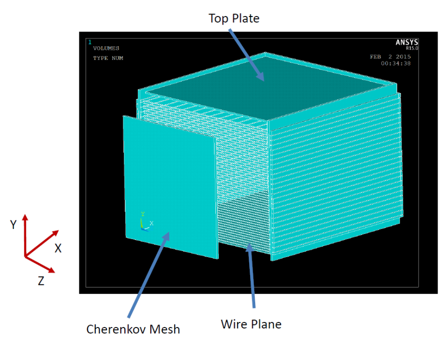
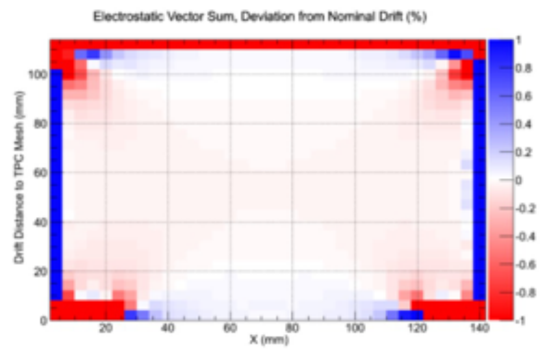
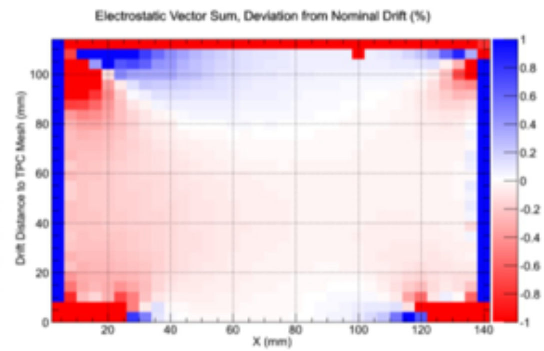




No Cherenkov mesh



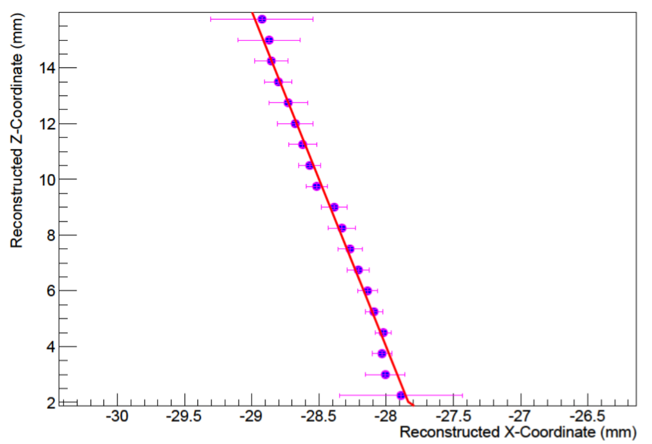
Cherenkov mesh 15 mm from wire plane

- Field cage has been tested to its full operating voltage of 1 kV/cm, and exhibited no sparking or break down problems.

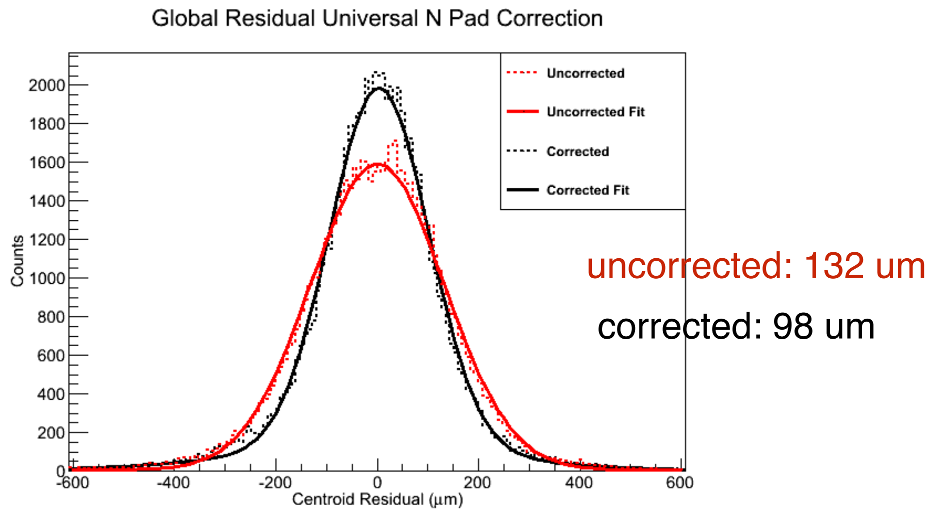
TPC Cherenkov Detector (BNL/SBU)

- The TPC GEM was configured into a **mini-drift detector** and tested with cosmic rays and x-ray source.
- Drift gap was 16 mm and used 2 mm x 10 mm chevron strips with a 0.5 mm zig-zag pitch for charge readout.
- Using highly collimated x-ray source yeilded a position resolution of 98 um (132 um) after correcting (not correcting) for non-linearity of the chevron pads

Reconstructed track from cosmic rays with GEMs configured as a mini-drift detector



Position Resolution



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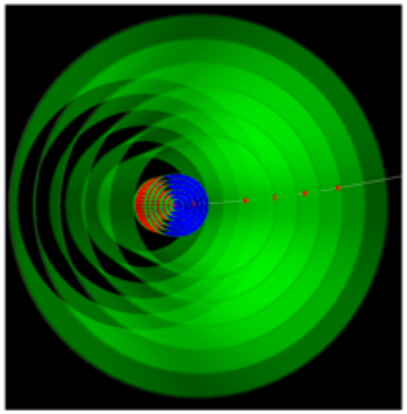
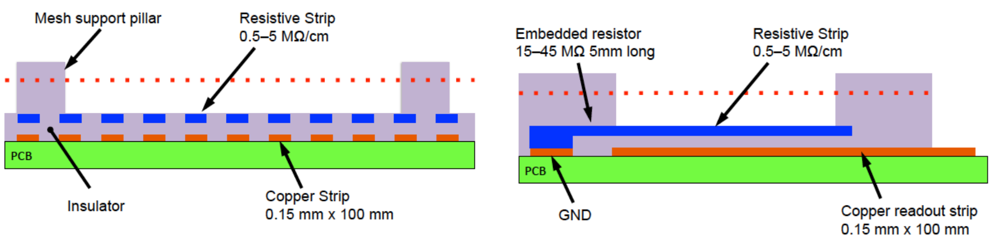
Barrel MMG (Saclay/TU)

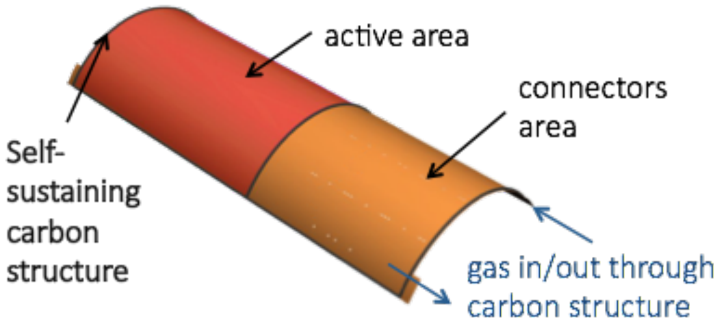
- Use resistive MMGs technology to build curved barrel detector in place of a TPC
- Tracking layers are formed by using cylindrical shells of increasing size (spanning ~10 - 60 cm)
- Allows for low material **alternative to using a TPC**
- Idea validated with CLAS12
- Transition to resistive technology → no measurable sparking





Resistive MMG

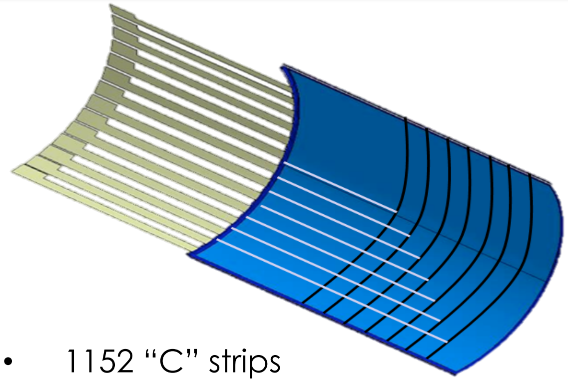
T. Alexopoulos et al., Nucl. Instrum. Meth. A640 (2011) 110.



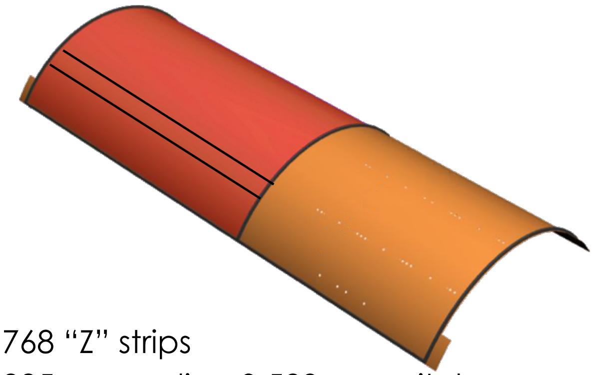
120° section

Maxine Vandenbroucke - EIC Meeting 2015

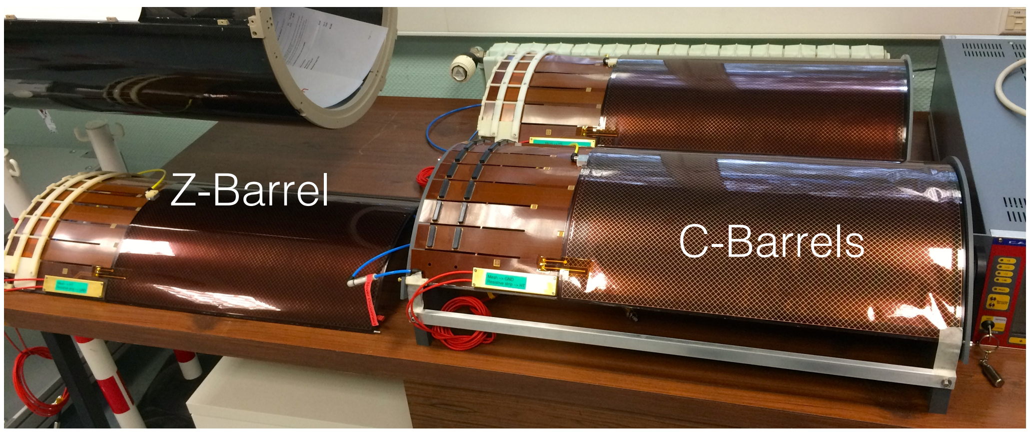
Barrel MMG (Saclay/TU)

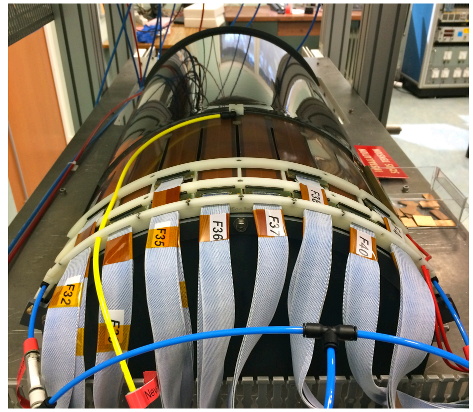


- 1152 "C" strips
- Pitch from 0.67 to 0.33 mm
- 221 mm radius
- PCB thickness 100 μm
- Drift thickness 250 μm
- Drift Field 2.4kV on 3 mm gap



- 768 "Z" strips
- 225 mm radius, 0.529 mm pitch
- PCB thickness 200 μm
- Drift thickness 250 μm
- Drift Field 2.4kV on 3 mm gap
- 0.37% of X0





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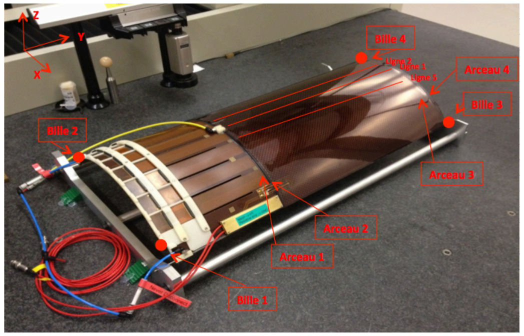
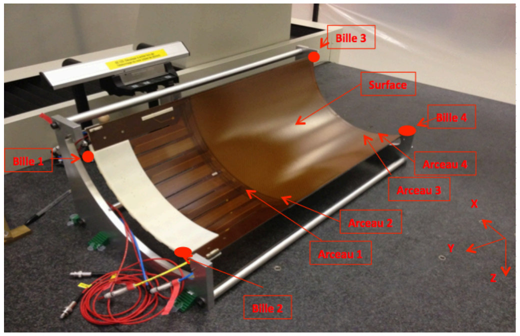
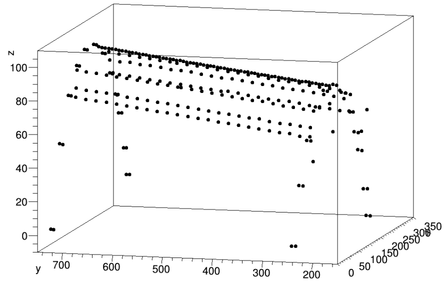
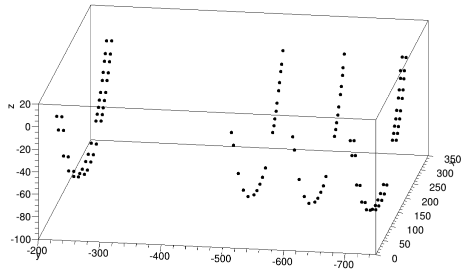
Barrel MMGs Structure Stability

- 3D probing machined used to measure geometric points
- 270 points measured on top (drift side)
- 120 points measured under (readout side)
- Cylindrical geometry precision of up to ~2mm in radius for Z-barrel









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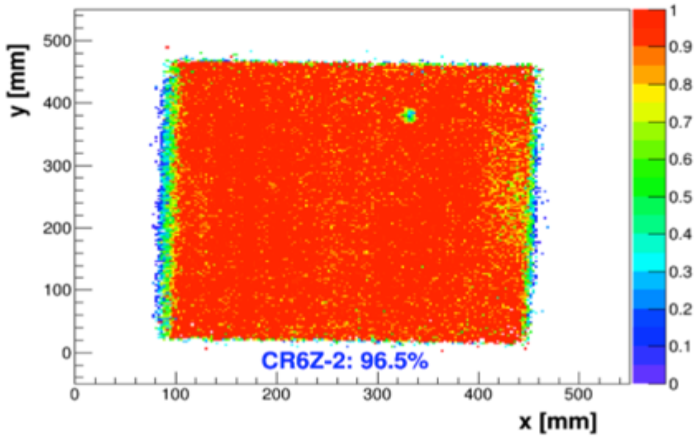
Barrel MMG (Saclay/TU)

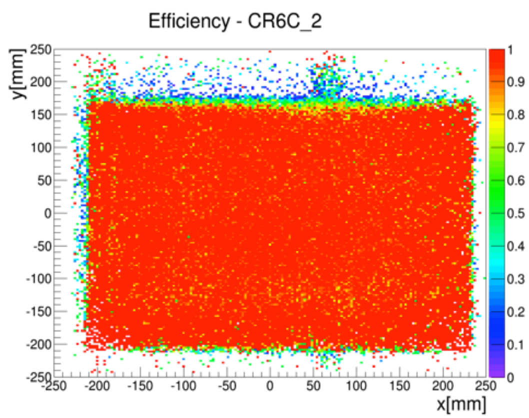
- Cosmic ray measurement results

Z-Barrel



96.5% Efficient

C-Barrel



98% Efficient

- Both detectors showed good efficiency (>95%)
- Spatial resolution better than 200 µm
- Timing resolution around 25 ns

eRD3 Progress Report June 2015

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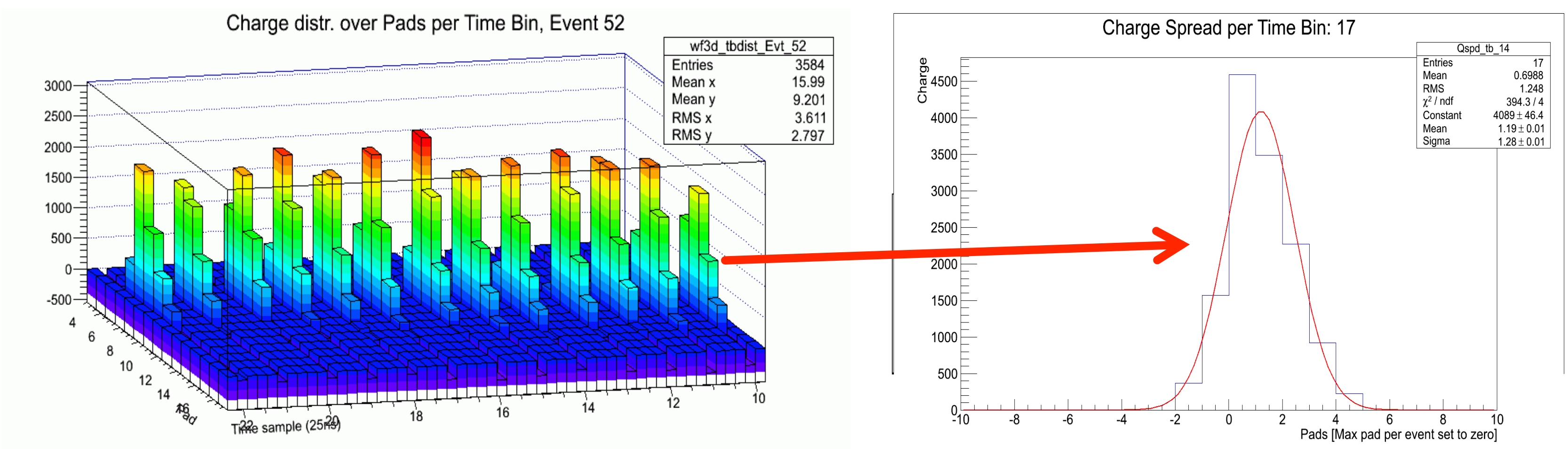
Summary

- The EIC gas tracking community is very active in developing gas trackers for potentia l use in an EIC
- There are many institutions involved in the R&D efforts: BNL, FIT, Saclay, SBU, TU, UVa, Yale
- Tracking solutions are being investigated for both the mid and forward/backward rapi dities, in an effort to provide fast, low mass, high resolution, and high efficiency detec tors.
- Some highlighted R&D efforts:
  1. Planar GEM detectors are being investigated to be used for track reconstruction, mo mentum measurements, and charge separation.
  2. Good track vector reconstruction was achieved through the use of a mini drift GEM detector.
  3. Study the possibility of using a hybrid TPC-Cherenkov detector to gain additional PID from a TPC tracker
  4. Look into using GEMs + MMG to try and reduce IBF from a TPC
  5. Investigate replacing a TPC with a series of MMG barrel detectors
- **Thank you!** And a special thanks to the eRD3 and eRD6 consortium

Backup

Mini-Drift GEM Tracker (BNL)

- Time slice method uses centroid found in each time bin and central time value of each time bin to fit a vector in the drift gap



More information found in arXiv:1510.01747

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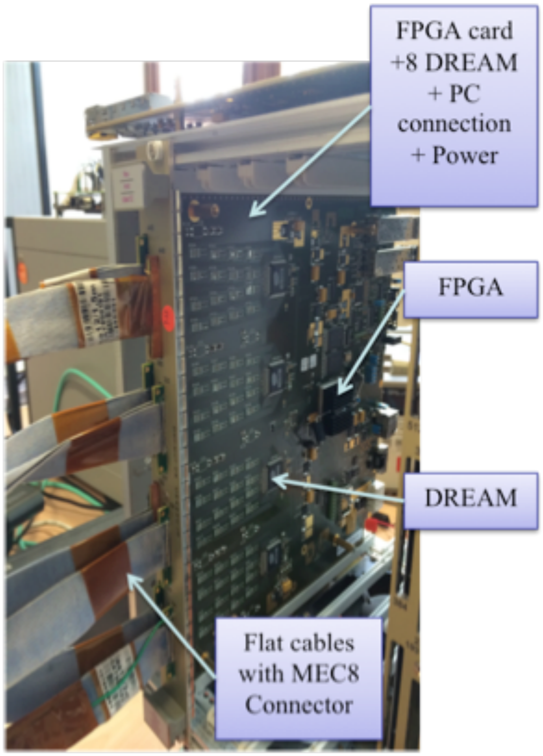
Dream-APV Chip Comparison



	Dream Chip	APV25-S1 Chip
Number of channels	64	128
Memory size	512	160
Latency	16μs	8μs
Noise (e-RMS)	2100 (On 180pF)	1200 (On 20pF)
Sampling frequency	1-40MHz	10-50MHz
Dynamic range	50-600fC	150fC
Input capacitance	150pF	18pF
Shaping time	70ns	50ns